Micromechanics Analysis Code (MAC) Developed

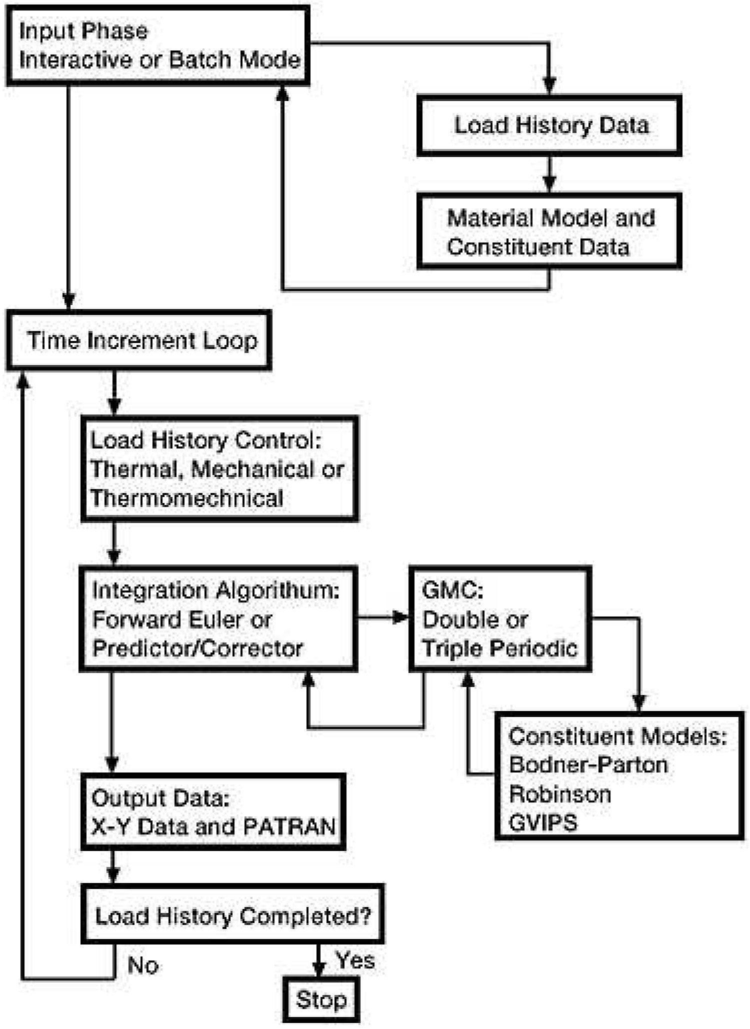
The ability to accurately predict the thermomechanical deformation response of advanced composite materials continues to play an important role in the development of these strategic materials. Analytical models that predict the effective behavior of composites are used not only by engineers in performing structural analysis of large-scale composite components but also by material scientists in developing new material systems.

For an analytical model to fulfill these two distinct functions, it must be based on a micromechanics approach that uses physically based deformation and life constitutive models, and it must allow one to generate the average (macro) response of a composite material given the properties of the individual constituents and their geometric arrangement. Only then can such a model be used by a material scientist to investigate the effect of different deformation mechanisms on the overall response of the composite and, thereby, identify the appropriate constituents for a given application.

However, if a micromechanical model is to be used in a large-scale structural analysis it must be (1) computationally efficient, (2) able to generate accurate displacement and stress fields at both the macro and micro level, and (3) compatible with the finite element method. In addition, new advancements in processing and fabrication techniques now make it possible to engineer the architectures of these advanced composite systems. Full utilization of these emerging manufacturing capabilities require the development of a computationally efficient micromechanics analysis tool that can accurately predict the effect of microstructural details on the internal and macroscopic behavior of composites. Computational efficiency is required because (1) a large number of parameters must be varied in the course of engineering (or designing) composite materials and (2) the optimization of a material's microstructure requires that the micromechanics model be integrated with optimization algorithms. From this perspective, analytical approaches that produce closed-form expressions which describe the effect of a material's internal architecture on the overall material behavior are preferable to numerical methods such as the finite element or finite difference schemes.

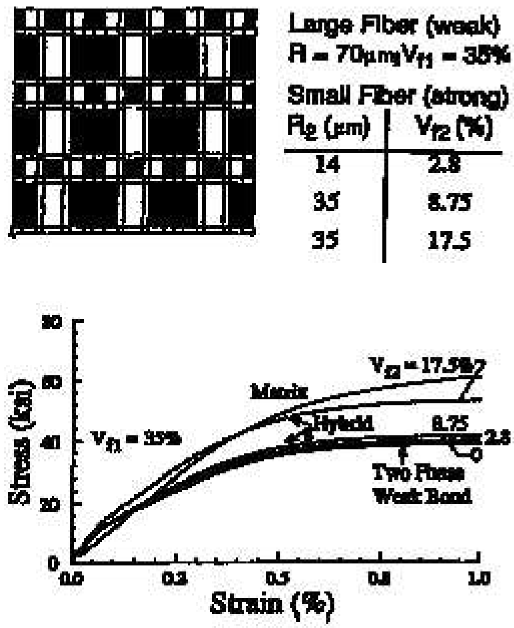
A number of existing models can fulfill some aspect of the aforementioned tasks. However, very few working models are both computationally efficient and sufficiently accurate at the micro and macro level. One such micromechanics model with the potential of fulfilling both tasks is the method of cells (ref. 1) and its generalization (ref. 2). The comprehensive capabilities and efficiency of this method are documented (refs. 3 to 5). Consequently, a computationally efficient and comprehensive micromechanics analysis code (MAC)--whose predictive capability rests entirely on the fully analytical micromechanics model herein referred to as the generalized method of cells (GMC) (refs. 2 and 3) was recently developed. MAC is a versatile form of research software that "drives" the double or triple periodic micromechanics constitutive models on the basis of GMC. GMC can predict the response of both continuous and discontinuous multiphased composites with an arbitrary internal microstructure and reinforcement shape. It is a

continuum-based micromechanics model that provides closed-form expressions for the macroscopic composite response in terms of the properties, size, shape, distribution, and response of the individual constituents or phases that make up the material. GMC also uses physically based viscoplastic deformation and life models for each constituent.



MAC flowchart.

MAC enhances the basic capabilities of GMC by providing a modular framework wherein (1) various thermal, mechanical (stress or strain control), and thermomechanical load histories can be imposed, (2) different integration algorithms can be selected, (3) a variety of constituent constitutive models can be utilized or implemented, and (4) a variety of fiber architectures can be easily accessed through their corresponding representative volume elements. The first figure illustrates the basic flow diagram for this modular framework, and the second figure illustrates MAC's ability to describe the influence of hybrid architectures on the transverse inelastic response of metal matrix composites.



Influence of hybrid architecture and bond strength on transverse inelastic response.

References

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